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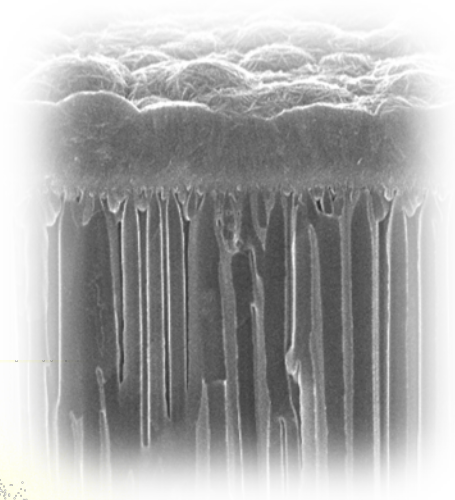

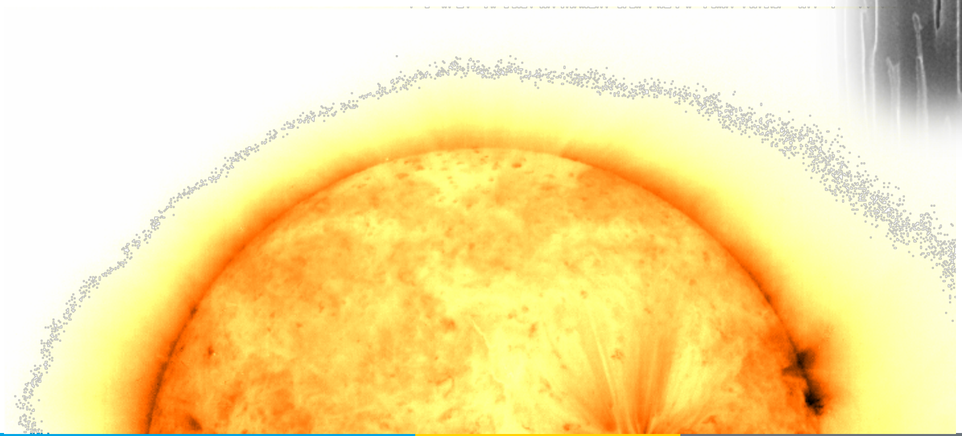

Transparent Conducting Coatings for Cost Effective Photovoltaics Manufactured Using Atomic Layer Deposition

Photovoltaics

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Overview

Timeline

- Project start: Feb 18, 2010
- Project end: Feb 28, 2013
- Percent complete: 8%

Barriers

- Low temperature process needed
- Maintain electrical isolation
- Achieve high materials performance
- Cost-efficiency

Budget

- Total project funding
  - DOE share: $945K
  - Industrial cost share:$450K
- Funding received in FY09: $0
- Funding for FY10: $945K

Partners

- Project lead: Argonne
- Industrial Partners:
  - Solasta, Inc.
  - SAFC Hitech

Challenges, Barriers or Problems

- A new cross-cutting technology is required to apply transparent conducting oxide (TCO) coatings onto next-generation photovoltaic devices. This technology must yield high performance TCOs at low process temperatures, and must be cost-effective.

- This new TCO coating technology will be applicable to a wide range of PV devices under development and in production in the US including nanocoaxial solar cells, dye-sensitized solar cells, nanostructured thin film solar cells, amorphous silicon solar cells, and multijuntion concentrated PV devices.

Relevance

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- Overall Objective: Lower the manufacturing cost ($/W) of photovoltaic devices by developing a new cross-cutting technology for the atomic layer deposition (ALD) of transparent conducting coatings to benefit a broad range of solar cells.
- Task 1: Develop a low-temperature ALD process for depositing indium-tin oxide (ITO) compatible with the Solasta nanocoaxial silicon PV manufacturing process
- Task 2: Develop an ALD process for depositing alternative transparent conducting coating using little or no indium.
- Task 3: Scale-up ALD transparent conducting coating process.

Approach

- ***Task 1 Go/No-Go Decision***: Performance of PV devices fabricated using ALD ITO coatings must be comparable or superior to those fabricated using conventional coatings.

- ***Task 2 Go/No-Go Decision***: Performance of PV devices using alternative transparent conducting coatings must be superior to those using ITO coatings.

- ***Task 3 Go/No-Go Decision***: Performance of scaled-up PV devices fabricated using ALD ITO coatings must be comparable or superior to those fabricated using conventional coatings.

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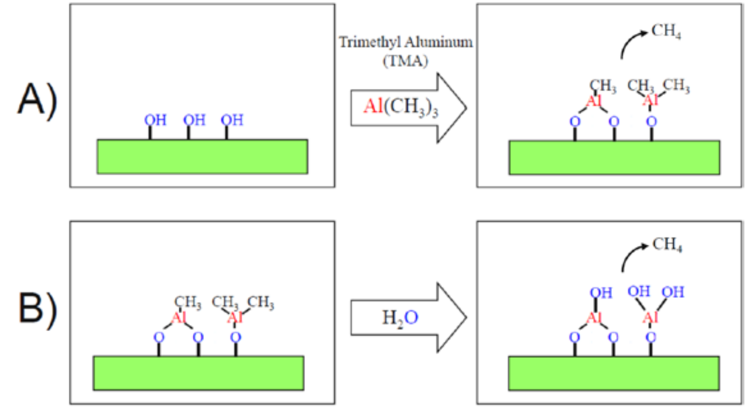
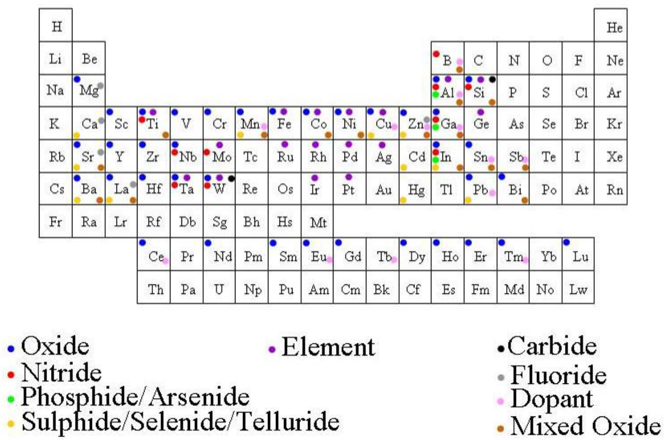
Atomic Layer Deposition (ALD):

Thin film coating method using alternating, self-limiting chemical reactions between gaseous precursors and a surface to deposit material in an atomic layer-by-layer fashion.

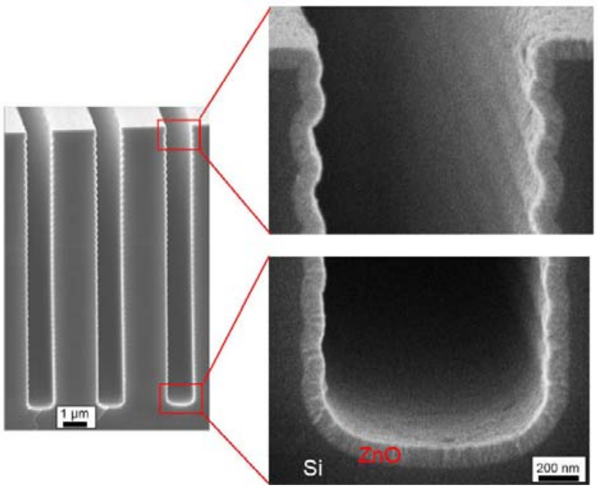


• Self-limiting surface reactions

ALD Thin Film Materials



• Many materials by ALD



• Conformal coatings over complex surfaces

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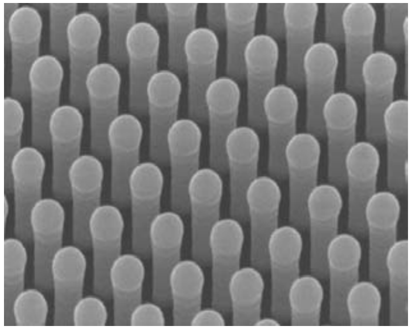
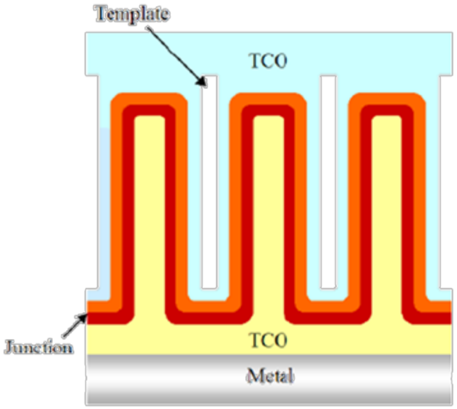
ALD Transparent Conducting Oxides (TCOs)

TCO Material	Resistivity (Ohm cm)	Transparency (%)	Sheet Resistance (Ohm)
Indium-tin oxide (ITO)	1.5×10^{-4}	90	30
Aluminum–zinc oxide (AZO)	1.0×10^{-3}	88	10
Antimony-tin oxide (ATO)	2.0×10^{-3}	90	100

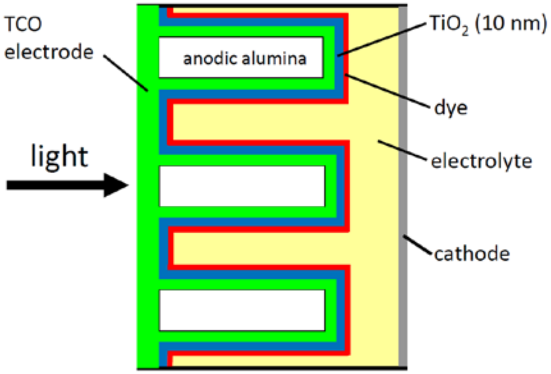
PV Technologies for ALD TCOs



Nanocoaxial silicon



Folded thin-film



Interdigitated DSSC

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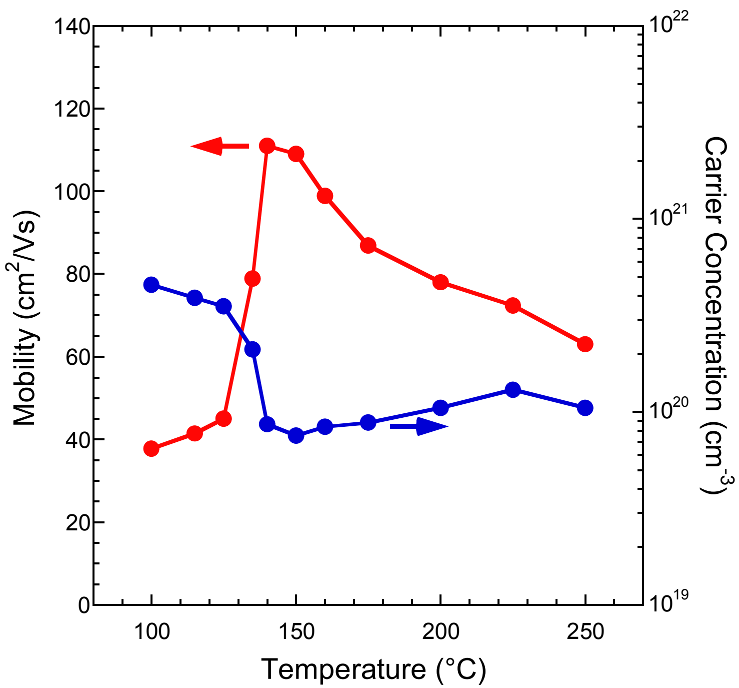
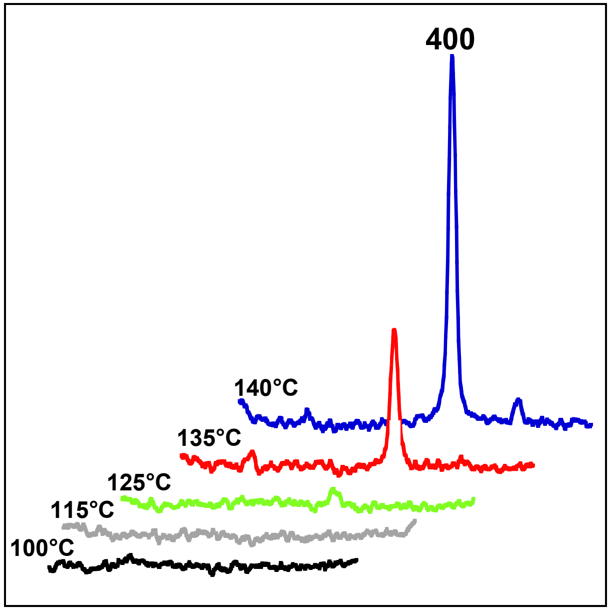
Collaborations

- Solasta, Inc.
  - Cost-sharing partner
  - Manufacture and evaluate nanocoaxial PVs utilizing the ALD technology developed in this program
- SAFC Hitech
  - Cost-sharing partner
  - Synthesize and characterize ALD precursors for use in TCO deposition

New Process for Indium Oxide ALD



- Dramatic increase in mobility at 140°C
- Dramatic decrease in carriers at 140°C



- amorphous to crystalline phase transition at 140°C
- Crystalline In_2O_3 has higher mobility, fewer defects

• Low temperature process, good materials properties

Budget Status and Potential for Expansion

- Project funding:
  - DOE share: $945K
  - Industrial cost share:$450K
- Project is on schedule and on budget

Future Plans (FY 2011 and beyond)

- FY10-11: Develop a low-temperature ALD process for depositing indium-tin oxide (ITO) compatible with the Solasta nanocoaxial silicon PV manufacturing process

- FY11-12: Develop an ALD process for depositing an alternative transparent conducting coating using little or no indium compatible with the Solasta manufacturing process.

- FY12-13: Scale-up ALD transparent conducting coating process.

Mandatory Summary Slide

Project Objective: Lower the manufacturing cost of photovoltaic devices by developing a new cross-cutting technology for the atomic layer deposition (ALD) of transparent conducting coatings to benefit a broad range of solar cells.

Partners: Argonne (lead), Solasta Inc., SAFC Hitech

Timeline: 2/18/10 – 2/28/13

Budget: $945K (DOE), $450K (industry cost-share)

Accomplishments: Low temperature In_2O_3 ALD process developed

Status: On schedule, on budget